U.S. DEPARTMENT OF THE INTERIOR
NATIONAL BIOLOGICAL SERVICE

INFORMATION AND TECHNOLOGY REPORT 4

AERIAL SURVEYS OF WATERBIRDS IN ALASKA 1957-94: POPULATION TRENDS AND OBSERVER VARIABILITY

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AUGUST 1996

AERIAL SURVEYS OF WATERBIRDS IN ALASKA 1957-94: POPULATION TRENDS AND OBSERVER VARIABILITY

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Aerial Surveys of Waterbirds in Alaska 1957-94: Population Trends and Observer Variability

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Abstract. Since 1957, major breeding populations of ducks in Alaska have been consistently monitored with strip-transect sampling from aircraft. By 1964, most other large waterbird species had been added to the survey. From 1957 to 1994, the population sizes of dabbling ducks (*Anas* spp.) generally remained stable. The populations of diving ducks (*Aythya* spp.) and sea ducks (*Bucephala* spp., *Clangula hyemalis*, and *Melanitta* spp.) except those of the merganser (*Mergus* spp.) and the canvasback (*Aythya valisineria*) declined by 15-75% during 1976-94. The population sizes of eiders (*Polysticta stelleri* and *Somateria* spp.) declined by 90% since 1957. We have also determined and present here the population distributions of all species and the population-size trends of loons (*Gavia* spp.), geese (*Anser albifrons, Branta* spp., and *Chen canagica*), swans (*Cygnus* spp.), and cranes (*Grus canadensis*). Improved survey conditions with a change of aircraft type in 1977 allowed us to count more birds, resulting in an apparent but artificial and instantaneous increase in the population-size index of all species of ducks. An analysis of the observers revealed that pilot duties caused only a 6.25% reduction in the number of observations counted alternately from the pilot and observer seats. The number of observations by other observers in the copilot seat were generally in close agreement with the pilot.

Key words: Waterfowl, distribution, transect, duck, goose, swan, loon, crane, temporal comparisons.

The purpose of the survey of waterfowl breeding in North America was to provide reliable population-size estimates of most duck species in North America and to monitor annual population-size changes in a large portion of the breeding grounds for annual adjustments of hunting regulations (U.S. Fish and Wildlife Service-Canadian Wildlife Service, 1987, Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Department of the Interior, unpublished.). In area of coverage and length of uninterrupted history, the survey has been the world's largest inventory of wildlife. The survey area is slightly larger than 3.5 million km^2 or about 10% of North America's land mass; it extends from Montana and South Dakota through Canada and into Alaska (Bellrose 1980; Smith 1995). A total of 2.4 million km flown during 1955-94 provided historical population data useful for far more than just setting hunting regulations.

The inevitable rotation of observers in the survey plane's right seat has long been a concern as a potential source of inconsistency (Hansen 1984). Inconsistencies or observer variability can be caused by differences in the observers' visual acuities, experience, and commitment, and their abilities to locate the 200-m transect boundary and to identify species. Alaska is the only portion of the North American survey area where data have been consistently preserved by observer, allowing us to study observer effects. Furthermore, one of us was the pilot during the entire survey period of 1957-94. These circumstances provided an unprecedented opportunity to analyze population-size changes in waterfowl through an extended period of time, compare recordings by observers with recordings by pilots, compare recordings among observers, and determine the effects of different aircraft types on the collected data.

Survey Area

The survey area includes most of the major waterfowl summer habitats in Alaska (Fig. 1). Exceptions include the wetlands near the Arctic Ocean coast (North Slope) and the small wetlands near the Pacific Ocean from the Aleutian Islands through the southeastern panhandle. The survey area consists of 11 sites (hereafter termed "strata") that are geographical delineations and not population-density stratifications (Table 1). Four of the strata (8, 9, 10, and 11) are in the tundra habitats of western Alaska, and the remaining seven interior strata are located primarily in boreal forest (taiga) habitat. Precise records of the original stratum boundaries were not kept and are therefore unknown.

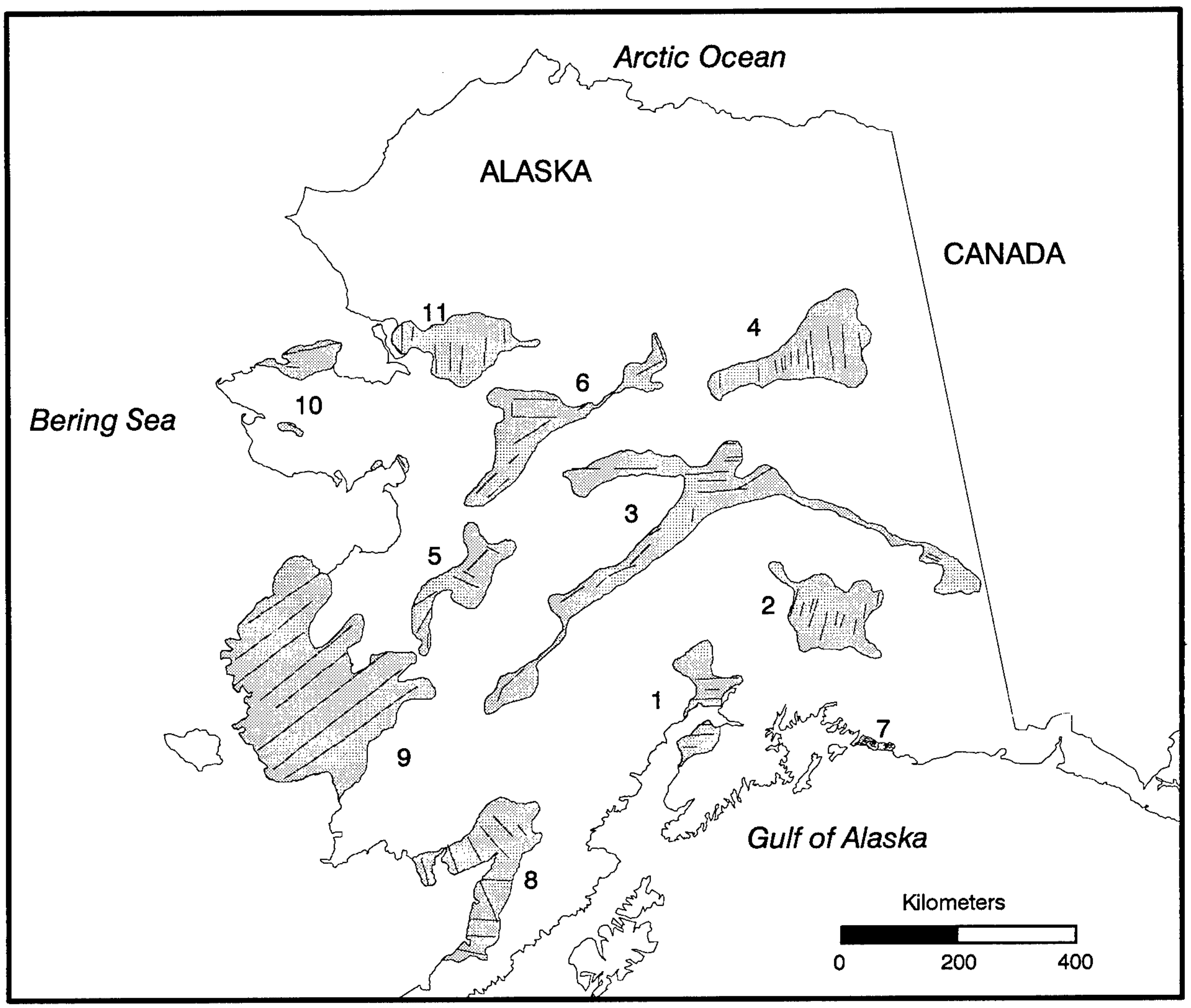


Fig. 1. Approximate boundaries of the 11 areas (strata) in which summering waterbirds (Gaviidae, Anatidae, Gruidae) were surveyed in Alaska, 1957-94, and locations of 92 transects. For names of strata, see Table 1.

Table 1. Strata for the survey of breeding waterbird populations in Alaska (See Fig. 1 for locations).

Stratum number	Stratum name	Original stratum size (km^2)	Sample size (km^2)	Percent sampled (%)
1	Kenai-Sustina	5,700	104	1.8
2	Tanana-Kuskokwim	10,100	135	1.3
3	Nelchina	24,100	342	1.4
4	Yukon Flats	28,000	207	0.7
5	Innoko	8,800	114	1.3
6	Koyukuk	10,600	207	2.0
7	Copper Delta	1,000	52	5.2
8	Bristol Bay	25,600	238	0.9
9	Yukon Delta	68,900	673	1.0
10	Seward Peninsula	10,000	73	0.7
11	Kotzebue Sound	13,900	124	0.9
	Total	206,700	2269	1.1

Definitions

We define the term **overflight** as the northward shift of northern pintails (*Anas acuta*) when drought conditions occur on the prairies (Smith 1970; Derksen and Eldridge 1980). **Tundra scaups** occur in the tundra habitats and are primarily greater scaups (*Aythya marila*). **Taiga scaups** occur in the taiga or interior habitats and are primarily lesser scaups (*A. affinis*). **Dabbling ducks** include the tribe Anatini. **Diving ducks** include the tribe Aythyini and genus *Bucephala*. **Miscellaneous ducks** are all other ducks. The **pilot-observer** pilots the plane and also serves as observer while piloting. An **observer** sits in the copilot seat (right front seat) and does not have piloting duties.

Methods

The survey was conducted in accordance with the standard operating procedures for aerial surveys of waterfowl on breeding grounds (U.S. Fish and Wildlife Service-Canadian Wildlife Service, 1987, Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Department of the Interior, unpublished). The survey was made along transects that consisted of one or more 26-km-long segments. Sampling was conducted on 224 segments. Waterfowl were sampled in an average 1.1% (range 0.7-5%) of the total area of each stratum. Observations were made from single-engine aircraft at an altitude of 30-40 m and a speed of 155 km/h. The pilot served as observer on the left side of the aircraft, and the occupant of the copilot's seat served as observer on the right side. Each observed birds within a 200-m distance from the flight path of the airplane and recorded the sightings with tape recorders. The same transect lines (with some alterations made during 1957-63) were used, and sampling was conducted in the same manner during all years. All identifiable waterbirds (Gaviidae, Anatidae, Gruidae) except gulls, terns, and shorebirds (Charadriiformes) were recorded by segment. All original dictabelts and magnetic tapes were preserved.

Aircraft types for the survey were a Piper Pacer on straight floats (1957-58), Cessna 180 on straight floats (1959-63), Cessna 180 on amphibious floats (1964-66), deHavilland beaver (Standard) on amphibious floats (1967-74), Cessna 185 on amphibious floats (1975-76), and deHavilland beaver (Modified, Turbine) on amphibious floats (1977-94).

The observations of ducks were adjusted according to the protocol of the U.S. Fish and Wildlife Service and the Canadian Wildlife Service (1987. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Department of the Interior, unpublished). Lone female ducks were not counted. The number of male ducks unaccompanied by female ducks was doubled to account for the female duck that was not seen but assumed to be present. Male scaups were not doubled because of the propensity for two or more males to accompany one female. If five or more males were in a group, their numbers were not doubled because it was assumed that each was not attending a breeding female. The population-size estimates of ducks were the products of the numbers of indicated ducks (as defined previously) per square kilometer, the number of square kilometers, and a visibility correction factor.

Unlike in other portions of the continent, ground surveys were not conducted in Alaska to annually correct data collected by the aerial crew and thereby adjust the inventory for unidentified ducks, misidentified ducks, and unseen ducks. In lieu of annual ground surveys, personnel in Alaska used helicopters to develop visibility correction factors, a ratio of actual ducks present to ducks seen from the aircraft (Table 2; Smith 1995). Comparisons of sightings from helicopters with sightings from fixed-wing aircraft during 3 years in taiga habitat (1986-88) and during 3 years in tundra habitat (1989-91) provided the visibility correction factors that we used. Because these corrections were not

Table 2. Visibility correction factors, or estimated ratios of actually present birds to observed birds in Alaska (Smith 1995).

Species	Taiga	Tundra
Mergansers (*Mergus* spp.)	1.27	1.27
Mallard (*Anas platyrhynchos*)	3.57	4.01
American wigeon (*Anas americana*)	3.65	3.04
Green-winged teal (*Anas crecca*)	8.88	8.36
Northern shoveler (*Anas clypeata*)	3.35	3.79
Northern pintail (*Anas acuta*)	2.51	3.05
Canvasback (*Aythya valisineria*)	2.43	2.43
Scaups (*Aythya affinis* and *A. marila*)	1.82	1.93
Goldeneyes (*Bucephala clangula* and *B. islandica*)	3.61	3.61
Bufflehead (*Bucephala albeola*)	1.86	1.86
Oldsquaw (*Clangula hyemalis*)	1.99	1.87
Eiders (*Somateria* spp.)	3.58	3.58
Scoters (*Melanitta* spp.)	1.08	1.17

calculated annually, we assumed that they represented an average compensation for various observers, phenology, and weather. Reliable visibility correction factors were not available for species other than ducks; therefore population-size estimates of non-duck species were unadjusted minimum values.

Unidentified ducks posed a problem during the early years of this data set, 1957-61, when roughly 20% of all ducks were classified as unidentified. The survey protocol at that time encouraged use of the unidentified species category when the observer was not confident of the identification. The number of unidentified ducks was included in the all-ducks graph but not in the graphical analysis by species. This procedure may have reduced the accuracy of the data from the first 5 years for some species that were difficult to identify. Data from those years were not used to derive the fitted trend lines.

Simple linear regression techniques provided trend lines to the time series data. Correlation coefficients were used for tests of significance. Two regression lines were fit, one for data from the years before 1977 and one for data from the years since 1977. This break was necessitated by a significant change in aircraft type in 1977, from piston airplanes to a turbine deHavilland beaver. A natural logarithmic curve was fit to the population-size estimates of trumpeter swans (*Cygnus buccinator*), because this population grew exponentially during the time period surveyed. The estimated standard error for a point estimate on the regression line was used for the confidence limits at the 95% significance level for the population regression estimate in 1994 (Snedecor and Cochran 1973). The true confidence intervals should be slightly larger than reported because of some lack of independence between years. Estimates of population-size changes spanning the 1977 break point were calculated by adding the estimated change in the pre-1977 fitted line to the change in the post-1977 fitted line.

Because they were exceptionally high, the 1994 counts of tundra scaups (primarily *Aythya marila*) and Pacific loons (*Gavia pacifica* and *G. arctica*) were not included in our analyses. We speculate that many of these birds were enroute to Alaska's Arctic Coastal Plain and eastern Siberia but were counted in this survey in 1994 because their migration was delayed by an extremely late arrival of spring in the northern habitats.

To analyze the effect of adding piloting duties to an observer's mental workload in the plane, we used three persons that rotated frequently between pilot and copilot seats during several years of surveys. The difference in the number of birds seen between observations from the left (pilot's) seat and observations from the right (copilot's) seat was reported as a proportion of one observer to the other observer and can only be viewed as the combined effect on both observers. The total effect of the pilot-observer on the accuracy of the observations was the average of proportions across all species.

Density estimates and population-size estimates computed by stratum were the average of all years without adjustment for the change of aircraft in 1977.

Results

Population Sizes

Population-size estimates by species varied annually about fitted regression lines (Fig. 2). Regression line slopes and 1994 point estimates varied by species (Tables 3 and 4). Spatial distribution, density, and abundance throughout Alaska for each species were also different (Fig. 3).

The observed number of common loons (*Gavia immer*) declined slightly (19%) during the last 18 years but the change was not statistically significant. Red-throated loons (*G. stellata*) were more visible after the turbine beaver aircraft became the survey platform in 1977. Their abundance has declined significantly (58%) since that time.

Northern shoveler (*Anas clypeata*) numbers increased steadily through the survey period. Northern pintail (*A. acuta*) numbers remained unchanged. The overflights in 1968, 1973, 1977, and 1980 were manifested in Alaska as sharp peaks in these survey data. Tundra scaups declined steadily throughout the survey period, 35%. Goldeneye (*Bucephala clangula* and *B. islandica*) and bufflehead (*B. albeola)* numbers declined by an estimated 45% and 42%, respectively, during the period 1977-94. Oldsquaw (*Clangula hyemalis*) numbers have been in a steep decline since 1977, estimated at 75%. Eider (*Somateria* spp.) numbers declined further, by 90%. Scoter (*Melanitta* spp.) numbers have been in a slow, steady decline (40%) since the survey began in 1957.

White-fronted goose (*Anser albifrons)* numbers and population sizes of the combined races of Canada goose (*Branta canadensis*) have increased steadily since 1964. Emperor goose (*Chen canagica*) numbers declined an estimated 60% during the period 1964-94.

Interior Alaska swans were almost all trumpeter swans, whose population size increased exponentially from 1,700 in 1964 to 14,000 in 1990. The data during 1991-94 suggest that continued population growth in the sample areas may have halted in 1990. Tundra swan (*Cygnus columbianus*) numbers have increased by 186% since 1964 from 42,000 to 120,000.

Aircraft Effect

The observed number of ducks increased instantaneously in 1977 concurrent with the introduction of the turbine beaver aircraft in the survey. In 1977 dabbling ducks, diving ducks, and sea ducks were the highest ever recorded by category. One pilot-observer participated in the survey for 13 years before and 6 years after the use of the turbine beaver. His observations showed a significant increase in the numbers of 7 of 11 duck species between the two periods, and an average increase of 26% for all ducks combined (Table 5).

Observer Comparisons

Two of the observers, Pilot-observer 1 and Pilot-observer 2, piloted the plane during the 1963-94 surveys, including 5 years when they flew together and alternated as pilot. Fifteen other observers accompanied them (Fig. 4).

During the 5 years when Pilot-observers 1 and 2 made the surveys together, Pilot-observer 1 as pilot saw 85% as many birds as Pilot-observer 2, who was sitting in the copilot's seat. When the roles were reversed, Pilot-observer 1 saw 97% as many birds as the pilot, Pilot-observer 2 (Table 6). If both participants had the same increase in observations when switching from pilot to observer, the estimated negative effect of piloting on observation acuity was 6% for each person. Similar results were obtained from Pilot-observer 3 and Pilot-observer 2 during a 4-year period, when the observer acuity of each was reduced by an estimated 6.5% while piloting.

Discussion

The surveys of waterbirds in Alaska provided not only data for the development of the annual continental hunting regulations but also for an analysis of the trends of population sizes. Population sizes fluctuated yearly because of many sources of variation—such as the previous year's production, annual mortality, overflight from the prairies, seasonal phenology, or changing observers and weather conditions—and these fluctuations may be temporary. However, data from 38 consecutive years revealed more conclusive patterns of population-size changes.

The presented population-size estimates may not accurately represent actual statewide total abundances of some species because (1) the transect lines were not located systematically throughout all of the habitat areas; (2) the birds may not have been evenly distributed in the sample areas; and (3) the habitat boundaries may not represent the true amount of habitat in all strata. An extreme example was the poor sample coverage of the coastal portion of the Yukon Delta that was the key nesting area of brants (*Branta*

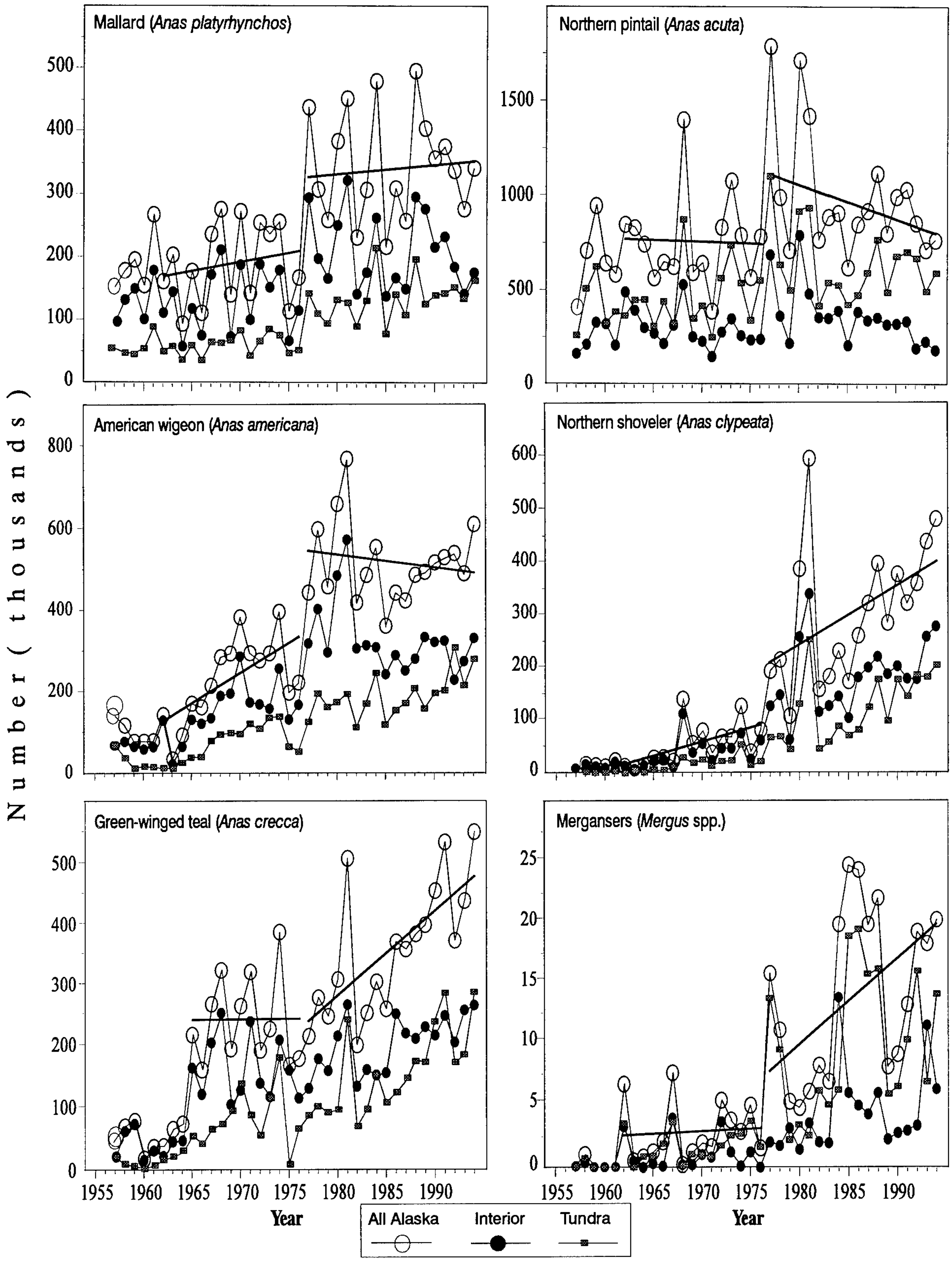
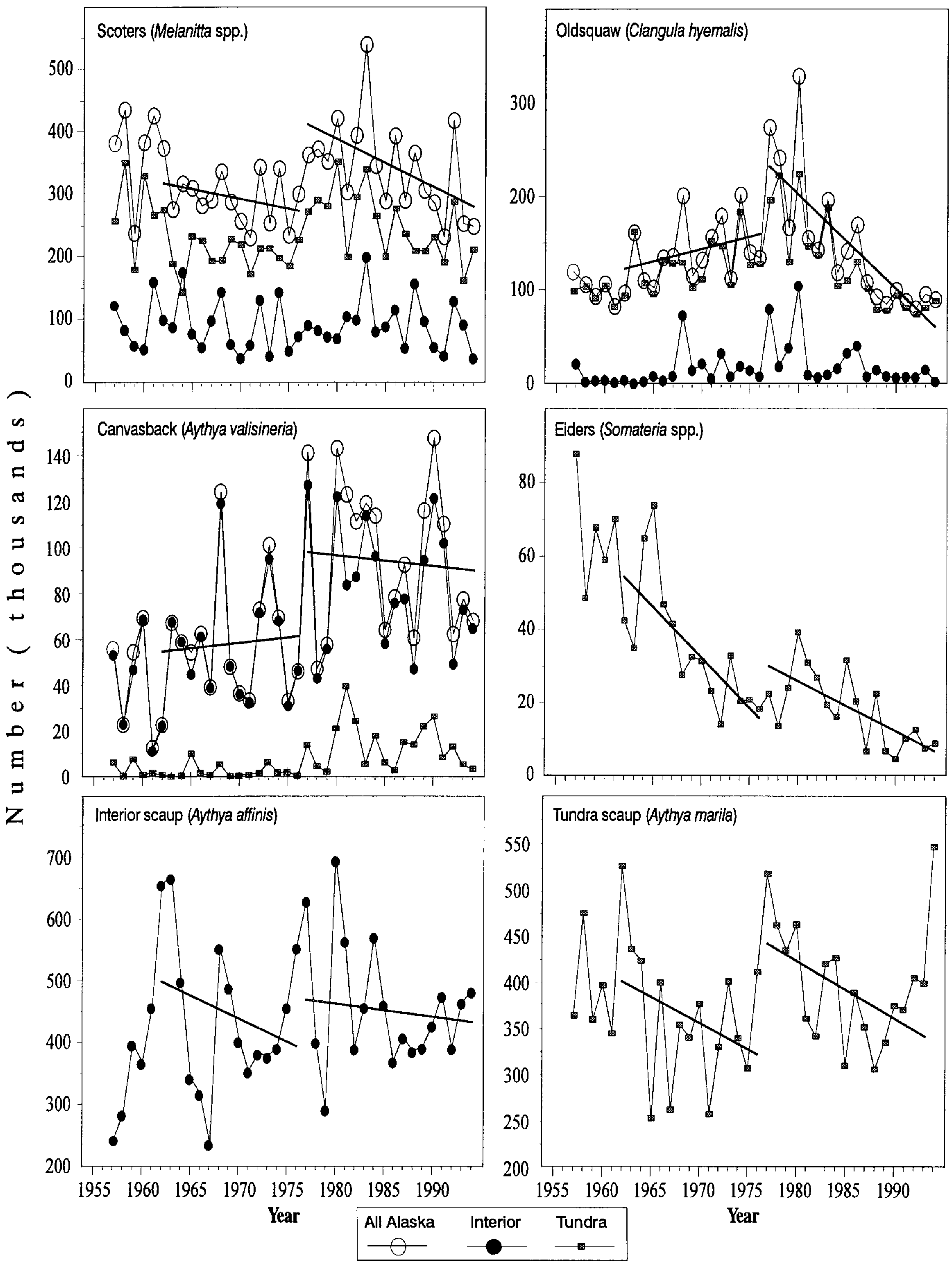


Fig. 2. Population-size trends in summering waterbirds (Gaviidae, Anatidae, Gruidae) in Alaska as estimated from survey data of summering birds in 1955-94. Change of aircraft type in 1977 necessitated fitting simple linear regression lines for both before and after that year.



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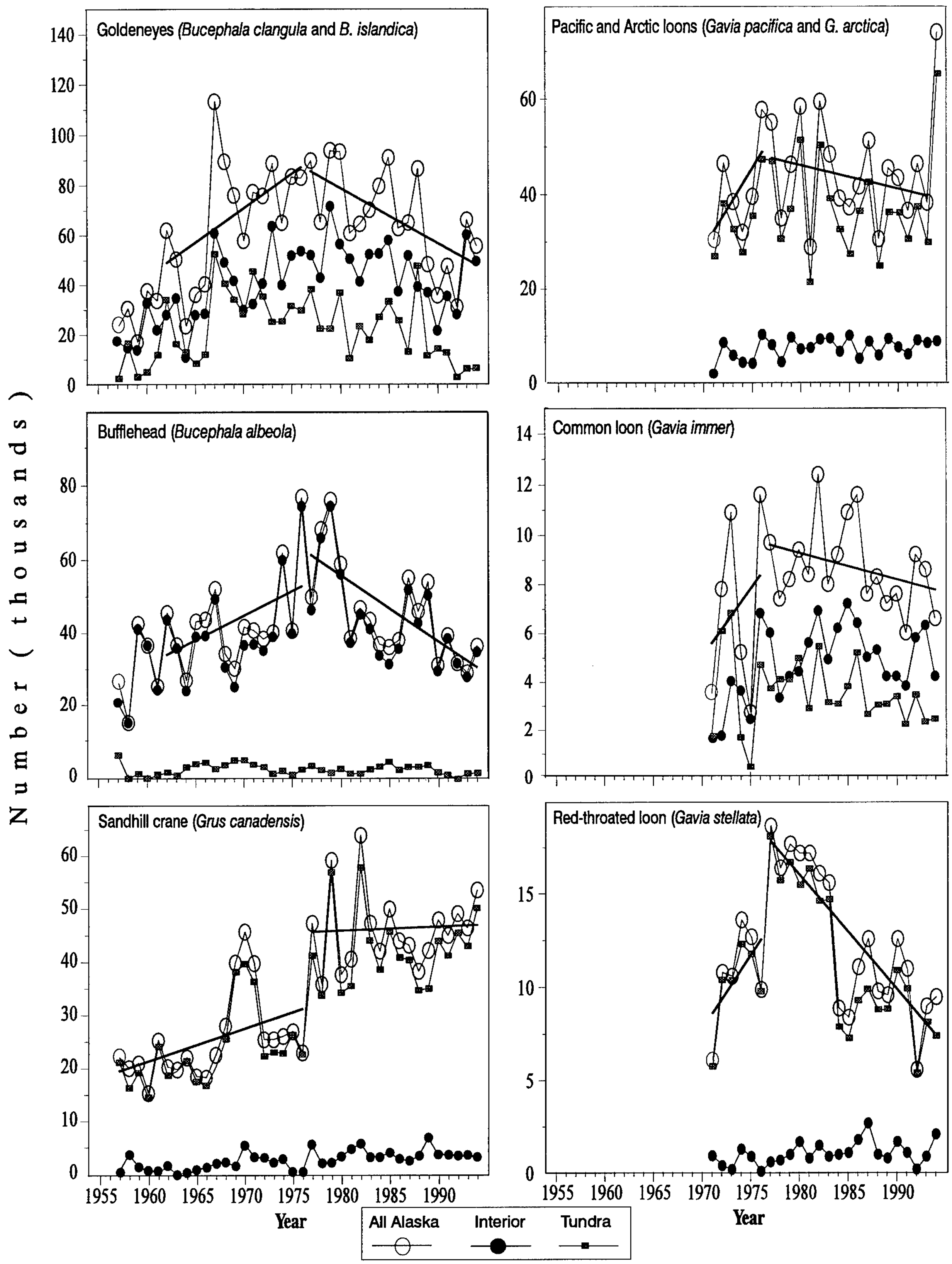

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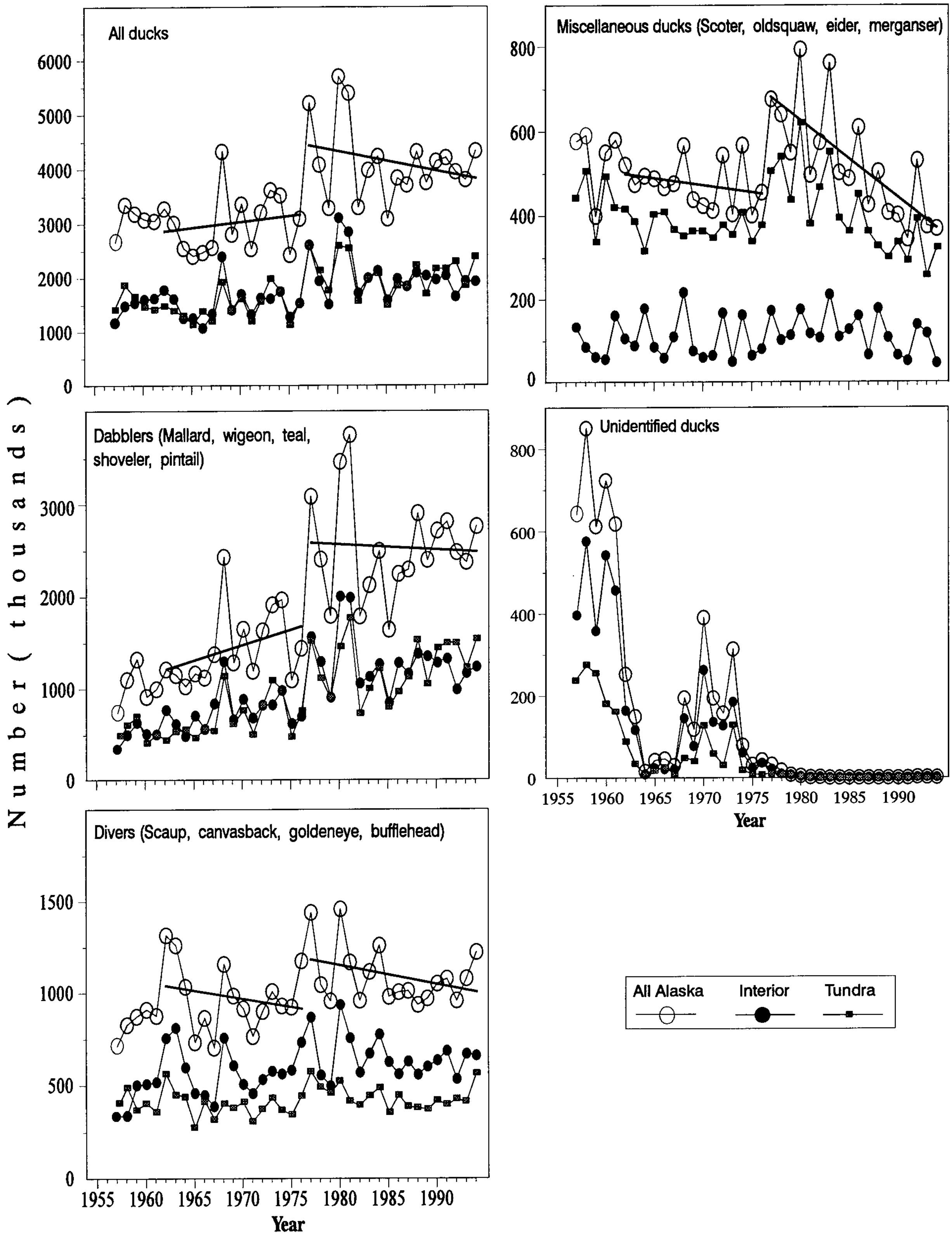

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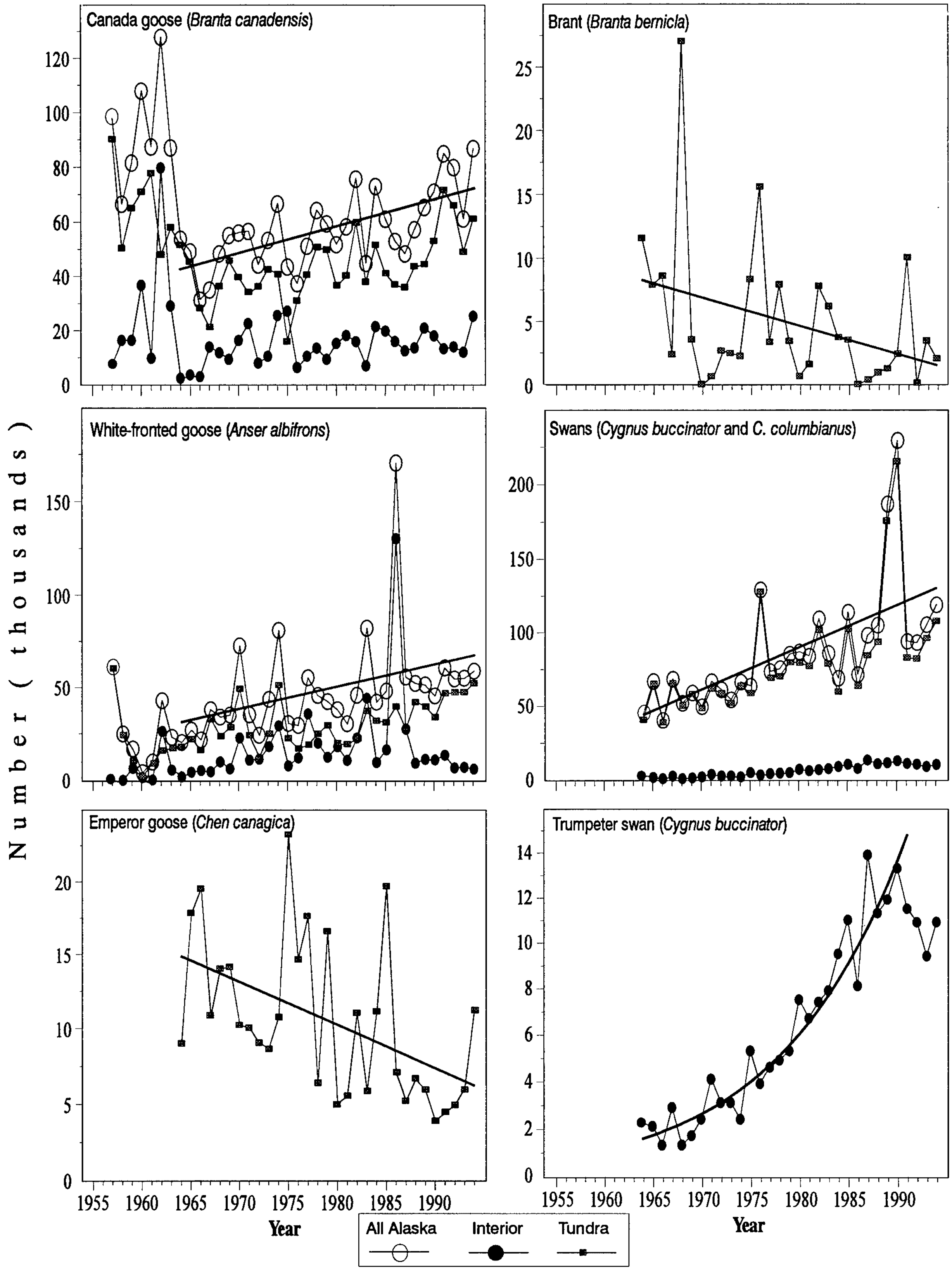


Fig. 2. Concluded.

Table 3. Simple regression lines before and after the turbine beaver aircraft was used for surveys of waterbirds in Alaska. The *R*-value represents correlation coefficient, slope represents estimated annual population change, and *P* is the probability under the null hypothesis of slope 0. The 1994 point estimate is the fitted line value in 1994. The population-size estimates of only ducks are corrected for visibility bias.

Species	1957-76			1977-94			1994	95% confidence interval as percent
	R	Slope	*P*	*R*	Slope	*P*	estimate	of estimate (%)
Common loon (*Gavia immer*)[a]	0.28	600	NS[b]	-0.35	-100	NS	8,000	± 19
Pacific/Arctic loon (*Gavia pacifica* and *G. arctica*)[a]	0.6	3,300	NS	-0.27	-500	NS	40,000	± 20
Red-throated loon (*Gavia stellata*)[a]	0.56	800	NS	-0.83	-600	0.0001	7,500	± 29
Mergansers (*Mergus* spp.)	0.07	400		0.51	700	0.04	20,000	± 30
Mallard (*Anas platyrhynchos*)	0.20	2,900	NS	0.09	1,500	NS	310,000	± 24
American wigeon (*Anas americana*)	0.65	14,700	0.002	-0.16	-3,100	NS	500,000	± 18
Green-winged teal (*Anas crecca*)	0.01	100	NS	0.68	14,100	0.004	450,000	± 17
Northern shoveler (*Anas clypeata*)	0.58	5,300	0.007	0.44	11,300	0.09	400,000	± 28
Northern pintail (*Anas acuta*)	-0.03	-1,500	NS	-0.34	-18,400	NS	750,000	± 32
Canvasback (*Aythya valisineria*)	0.08	500	NS	-0.07	-500	NS	90,000	± 33
Tundra scaup (*Aythya marila*)	-0.34	-5,700	NS	-0.55	-6,200	0.03	340,000	± 13
Interior scaup (*Aythya affinis*)	-0.27	-7,600	NS	-0.12	-2,200	NS	430,000	± 21
Goldeneyes (*Bucephala clangula* and *B. islandica*)	0.52	2,700	0.02	-0.59	-2,200	0.02	50,000	± 30
Bufflehead (*Bucephala albeola*)	0.48	1,300	0.03	-0.68	-1,800	0.004	30,000	± 33
Oldsquaw (*Clangula hyemalis*)	0.35	2,600	NS	-0.77	-10,100	0.0005	60,000	± 67
Eiders (*Somateria* spp.)	-0.73	-2,800	0.0003	-0.67	-1,400	0.005	7,000	± 100
Scoters (*Melanitta* spp.)	-0.33	-3,100	NS	-0.50	-7,700	0.05	280,000	± 21
Sandhill crane (*Grus canadensis*)	0.21	500	NS	0.08	100	NS	47,000	± 15

[a] Not surveyed before 1971.
[b] NS = not significant.

Table 4. Simple regression lines, 1964-94, for species in the Alaska survey that were unaffected by the turbine beaver aircraft. The *R*-value represents correlation coeficient, slope represents estimated annual population change, and *P* is the probability under the null hypothesis of slope 0. The 1994 point estimate is the fitted line value in 1994. Population-size estimates are uncorrected for visibility bias.

Species	*R*	Slope	*P*	1994 estimate	95% confidence interval as percent of estimate (%)
White-fronted geese (*Anser albifrons*)	0.40	1,200	0.03	68,000	± 26
Canada geese (*Branta canadensis*)	0.66	1,000	0.0001	70,000	± 10
Brant (*Branta bernicla*)[a]	0.36	-200	0.05	1,600	± 230
Emperor geese (*Chen canagica*)[a]	-0.50	-300	0.006	6,300	± 48
Tundra swan (*Cygnus columbianus*)	0.66	2,900	0.0001	120,000	± 17

[a]Brant and emperor geese estimates are low because sample transects failed to adequately cover their coastal nesting habitat.

bernicla) and emperor geese. These estimates are indices that should be comparable to actual but unknown population levels.

There is little doubt that the numbers of red-throated loons, tundra scaups, goldeneyes, buffleheads, oldsquaws, eiders, scoters, and emperor geese declined in the past two decades. Conversely, populations of northern shovelers, white-fronted geese, Canada geese, and swans increased. The cackling Canada geese of coastal Yukon-Kuskokwim Delta were not sampled well by our transect lines and therefore their documented population decline through most of the survey period (O'Neill 1979) was not represented with these data.

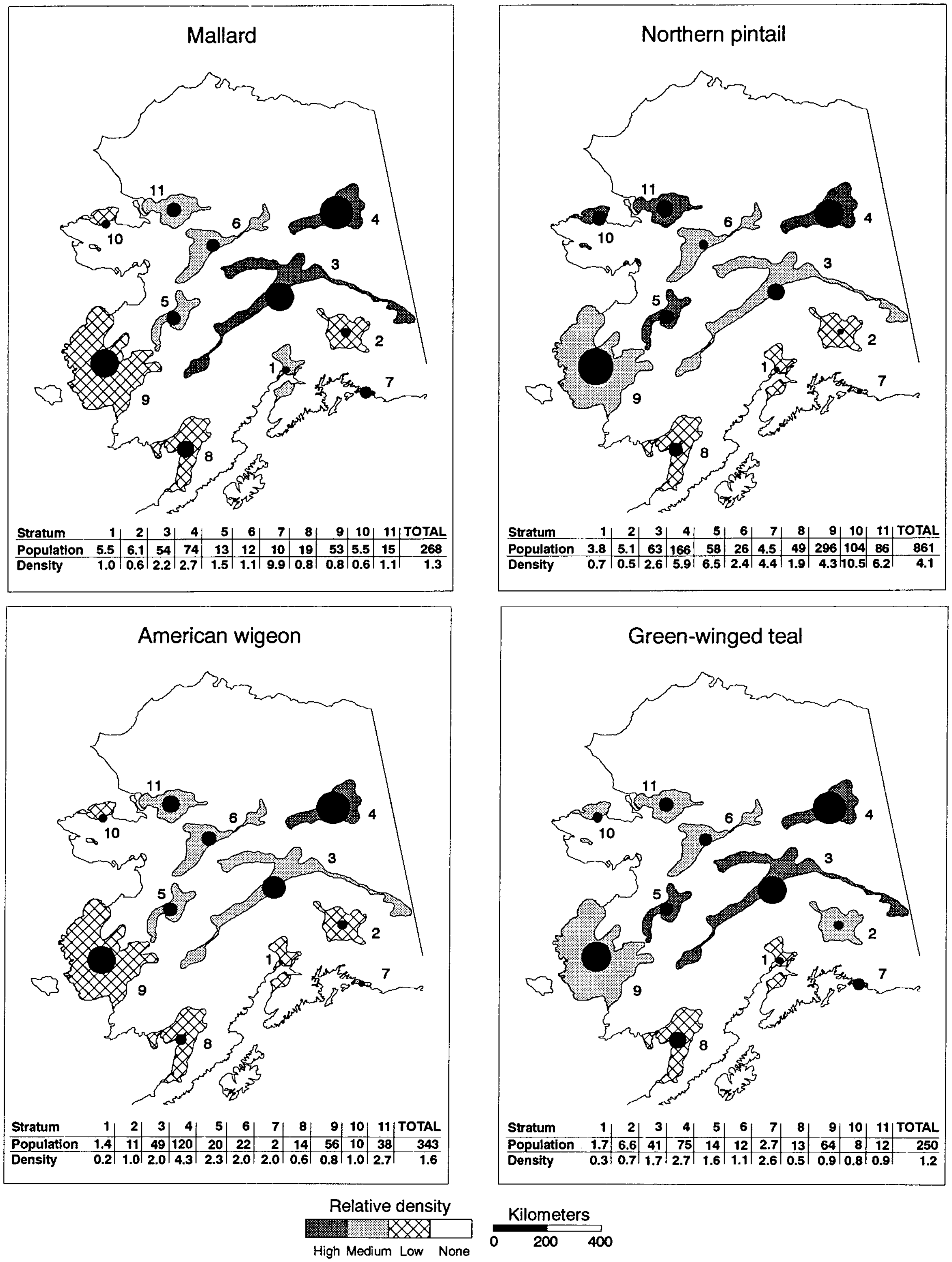
The exponential increase in the numbers of trumpeter swans demonstrated by our data matches the results of complete census counts conducted periodically during 1968-90 (Conant et al. 1992). Population-size estimates for swans between surveys are also comparable. The cause of the subsequent decline in the number of trumpeter swans recorded on our transects during 1991-94 is unknown.

The aircraft used for this type of survey had a significant effect on the results, detected only through the many years of data collected before and after the aircraft change. We can speculate on the reasons for the increase in the observed numbers of loons, ducks, and cranes associated with the change from reciprocating engine-powered Cessna and deHavilland beavers to the turbine beaver in 1977. The turbine beaver was designed specifically for this type of survey: it was quieter, afforded better visibility from the cockpit, and had an engine that required less attention from the pilot and performed better in sloping terrain. Observed numbers of geese and swans did not shift with the aircraft change to the turbine beaver, probably because all aircraft types flushed geese (except incubating females); thus these species were always highly visible. Swans are large and white, making them easily seen from all aircraft types.

The reduction (6.25%) in observations when an individual shifted from the observer side of the plane to the pilot's seat and assumed the pilot duties was expected. It was surprising that the effect was not larger in view of the additional piloting responsibilities. Pacific loons were expected to be more observable by the pilot than the observer because they frequently dove at the approach of the airplane and the pilot tended to spend proportionately more time looking forward. Indeed, these three observers saw more Pacific loons from the pilot's seat than from the observer's seat.

The purpose of the right-seat observer was to double the sample size and thereby reduce the variability of the counts. If observers were biased or consistently inaccurate, then changing observers annually would help average out errors but would also increase variability between years. If pilot-observers who participated in the survey for many years were biased, then a false change in species abundance could have resulted when such an individual was replaced. It was helpful to present the data by observer to search for these patterns. We found most observers to be in reasonable agreement with each other.

Because of its long history, the traditional breeding population survey currently is the most accurate measure of population-size changes in Alaska of



Mallard

Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	5.5	6.1	54	74	13	12	10	19	53	5.5	15	268
Density	1.0	0.6	2.2	2.7	1.5	1.1	9.9	0.8	0.8	0.6	1.1	1.3

Northern pintail

Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	3.8	5.1	63	166	58	26	4.5	49	296	104	86	861
Density	0.7	0.5	2.6	5.9	6.5	2.4	4.4	1.9	4.3	10.5	6.2	4.1

American wigeon

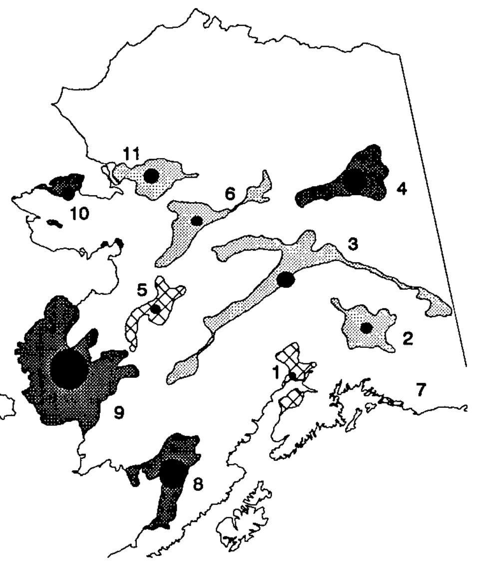
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	1.4	11	49	120	20	22	2	14	56	10	38	343
Density	0.2	1.0	2.0	4.3	2.3	2.0	2.0	0.6	0.8	1.0	2.7	1.6

Green-winged teal

Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	1.7	6.6	41	75	14	12	2.7	13	64	8	12	250
Density	0.3	0.7	1.7	2.7	1.6	1.1	2.6	0.5	0.9	0.8	0.9	1.2

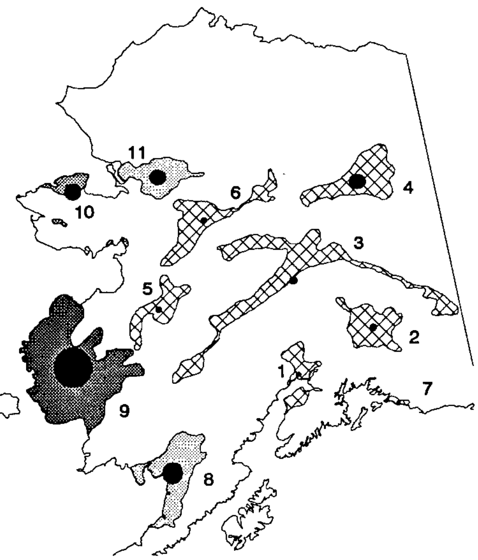
Fig. 3. Relative waterbird (Gaviidae, Anatidae, Gruidae) population sizes and distributions in Alaska based on the number of summering birds in 1957-93. Circled sizes are relative to total population size; shading intensity is proportional to population density. Darker shading indicates higher relative density. Long-term averages were used without adjusting for the change of aircraft in 1977. Population sizes are in thousands and density values are birds per square kilometer. Total densities are averages weighted by area.

Scoters



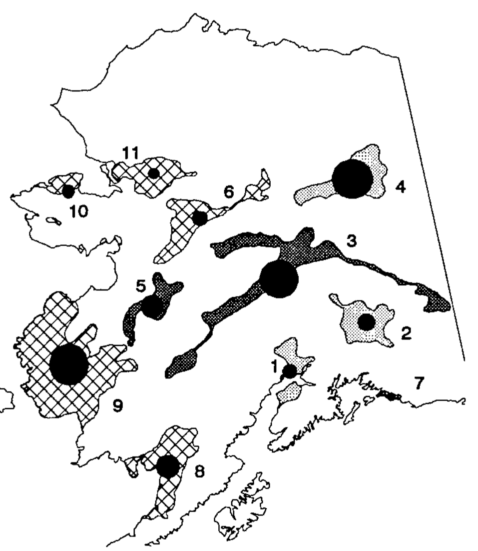
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	1.5	9.2	23	46	4.9	8.3	0.2	82	124	17	16	332
Density	0.3	0.9	1.0	1.6	0.6	0.8	0.2	3.2	1.8	1.7	1.1	1.6

Oldsquaw



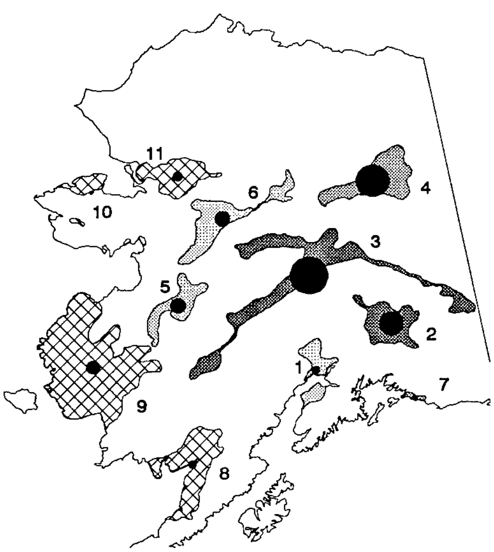
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.1	1.1	3.1	12	0.8	0.8	0.0	17	79	18	9.3	141
Density	-	0.1	0.1	0.4	0.1	0.1	0.0	0.7	1.1	1.8	0.7	0.7

Goldeneye



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	2.8	3.3	14	11	6.1	2.0	1.0	5.7	14	1.9	0.8	63
Density	0.5	0.3	0.6	0.4	0.7	0.2	0.9	0.2	0.2	0.2	0.1	0.3

Bufflehead



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.5	6.1	17	13	1.6	2.6	0.2	0.7	1.2	0.0	0.5	43
Density	0.1	0.6	0.7	0.5	0.2	0.2	0.2	-	-	-	-	0.2

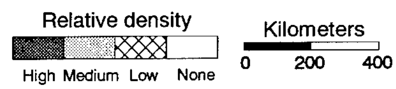
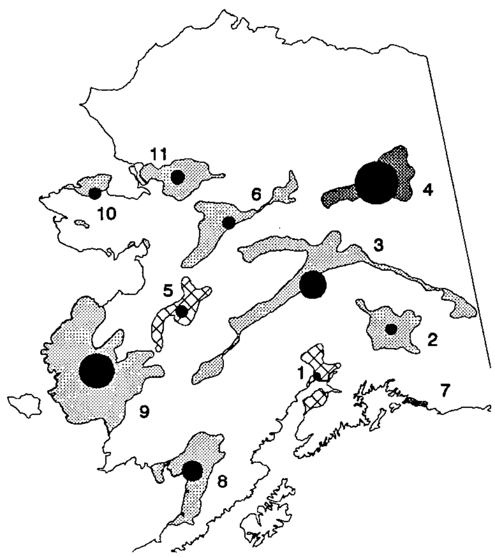


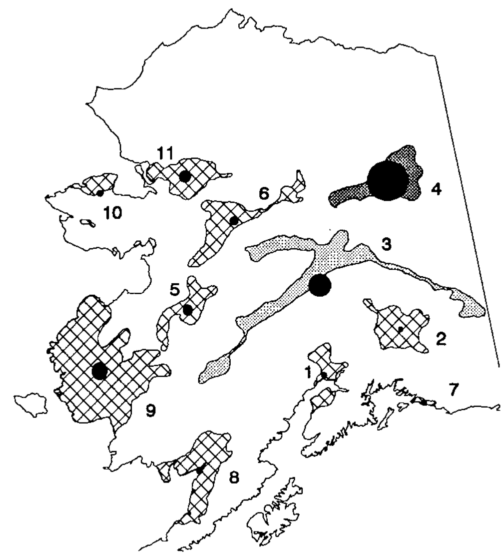
Fig. 3. Continued.

Scaup



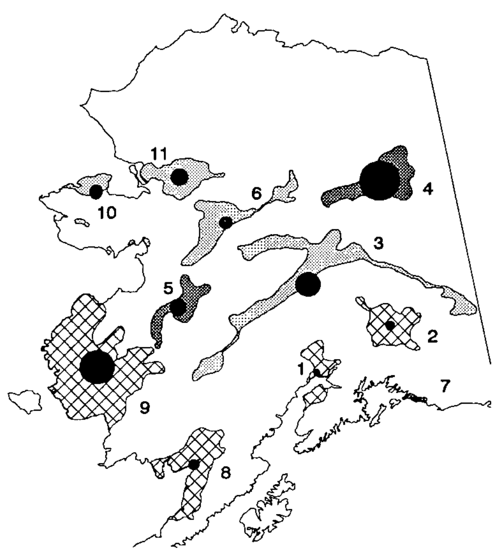
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	4.0	32	102	253	16	28	7.5	69	217	34	57	820
Density	0.7	3.2	4.3	9.0	1.8	2.7	7.2	2.7	3.2	3.4	4.1	3.9

Canvasback



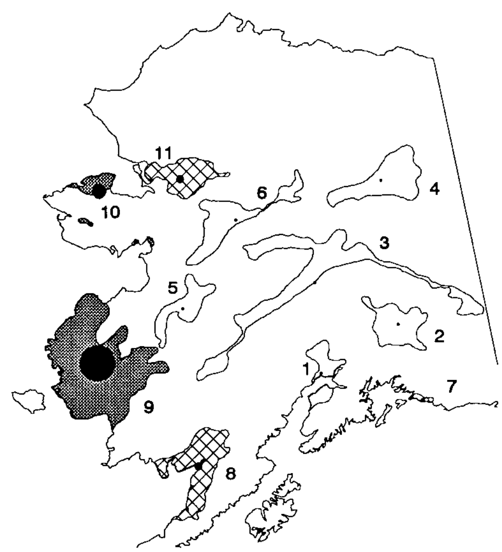
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.5	0.1	15	48	1.5	1.0	0.7	0.3	3.5	1.0	2.9	75
Density	0.1	-	0.6	1.7	0.2	0.1	0.7	0.0	0.1	0.1	0.2	0.4

Northern shoveler



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.6	1.6	21	56	12	7.6	1.8	4.9	34	8.4	13	160
Density	0.1	0.2	0.9	2.0	1.3	0.7	1.8	0.2	0.5	0.8	0.9	0.8

Eiders



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	27	3.1	0.5	32
Density	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.4	0.3	-	0.1

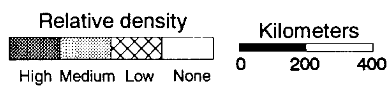
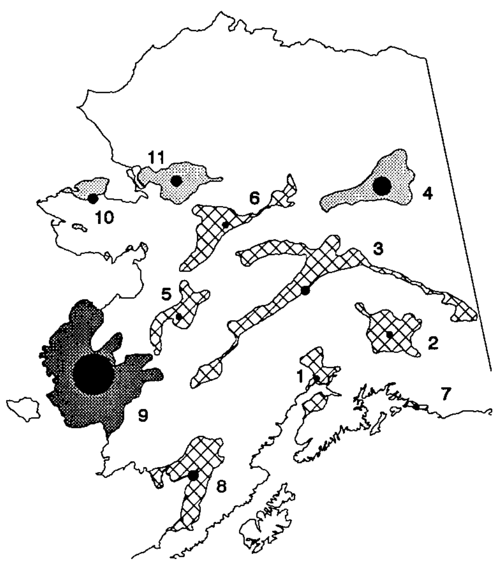


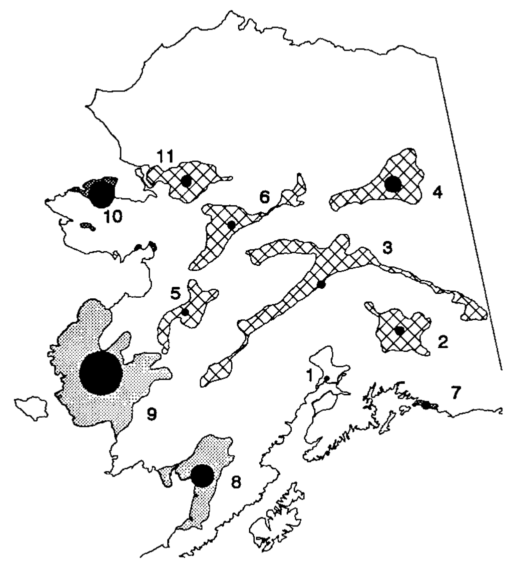
Fig. 3. Continued.

Pacific and Arctic loons



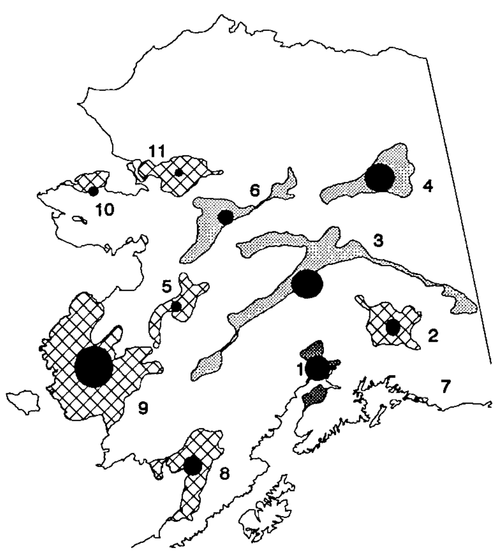
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.2	0.2	0.7	5.0	0.2	0.3	0.0	1.1	27	1.9	1.8	39
Density	-	-	-	0.2	-	-	-	-	0.4	0.2	0.1	0.2

Red-throated loon



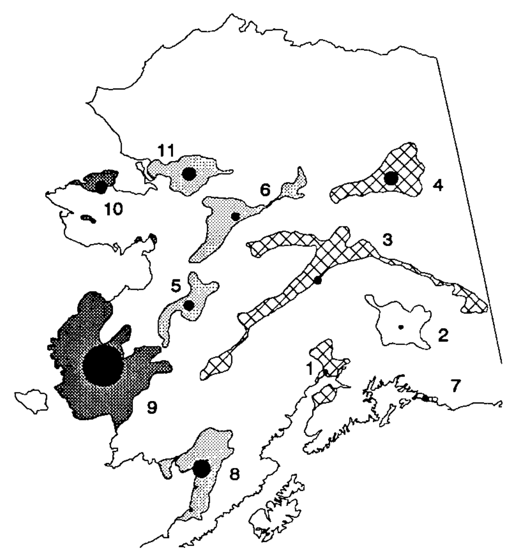
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.0	0.1	0.1	0.2	0.2	0.1	0.3	1.7	5.5	2.7	0.4	11.4
Density	0.0	-	-	-	-	-	0.3	0.1	0.1	0.3	-	0.1

Common loon



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	1.2	0.3	1.1	1.2	0.1	0.4	0.0	0.8	2.1	0.2	0.1	7.6
Density	0.2	-	-	-	-	-	0.0	-	-	-	-	-

Sandhill crane



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.1	0.0	0.6	1.1	0.7	0.6	0.0	3.0	24	3.9	2.8	37
Density	-	0.0	-	-	0.1	0.1	0.0	0.1	0.4	0.4	0.2	0.2

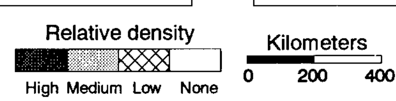
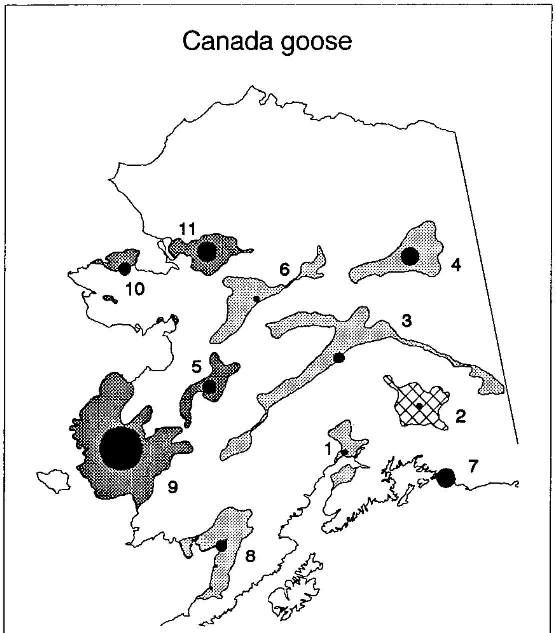
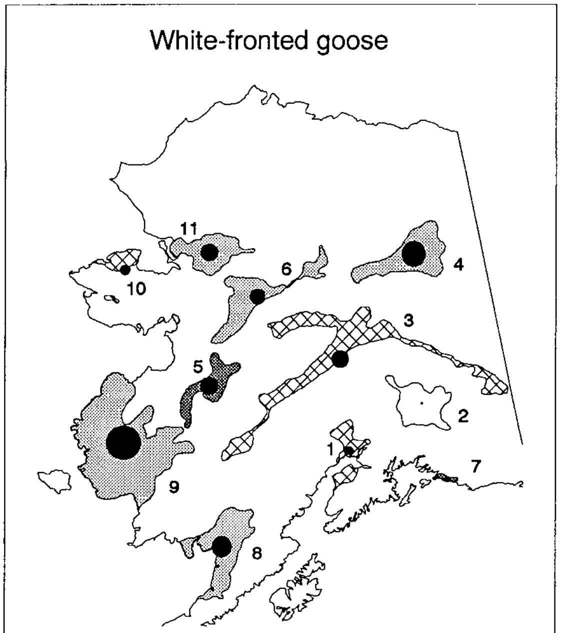


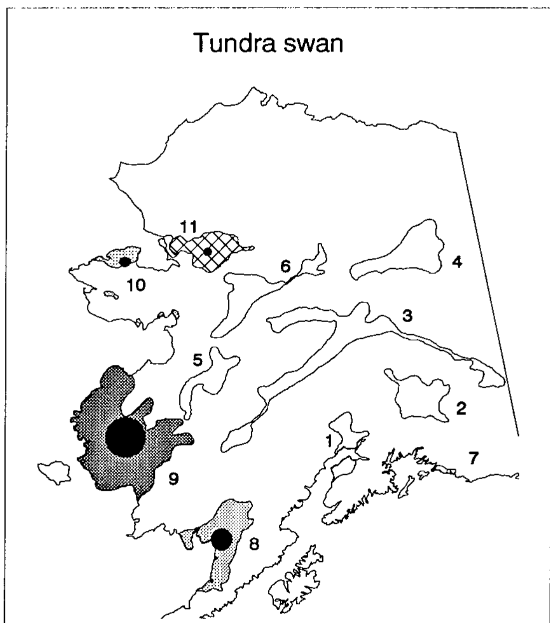
Fig. 3. Continued.



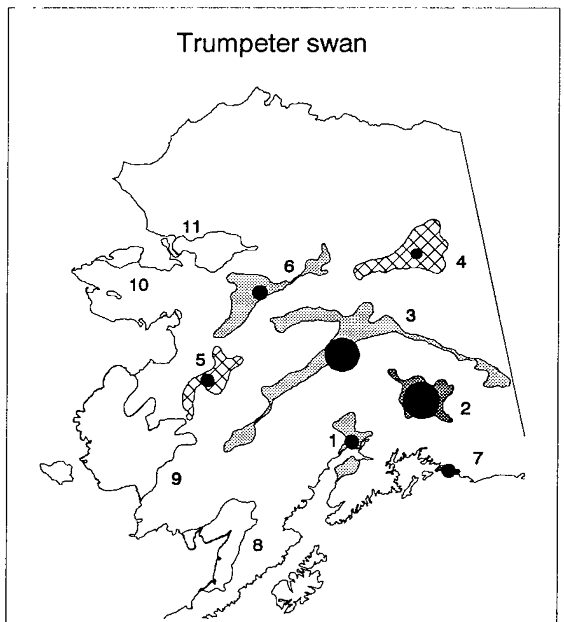
Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.7	0.2	1.4	5.5	4.1	0.7	10	1.8	34	4.3	7.1	70
Density	0.1	-	0.1	0.2	0.5	0.1	9.7	0.1	0.5	0.4	0.5	0.3



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.1	0.0	3.4	6.1	3.6	3.2	0.4	4.3	18	1.2	4.7	45
Density	-	0.0	0.1	0.2	0.4	0.3	0.4	0.2	0.3	0.1	0.3	0.2



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	-	-	-	-	-	-	-	13	58	4.0	3.3	78
Density	-	-	-	-	-	-	-	0.5	0.8	0.4	0.2	0.5



Stratum	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Population	0.4	2.4	2.3	0.1	0.3	0.5	0.5	-	-	-	-	6.5
Density	0.1	0.2	0.1	-	-	-	0.5	-	-	-	-	0.1

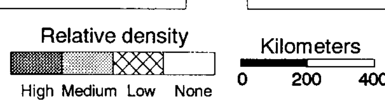


Fig. 3. Concluded.

Table 5. Percent change in observed numbers of waterfowl (Anseriformes) before (20 years) and after (17 years) the use of the turbine beaver aircraft. Observer 1's information includes data from 13 years before and 6 years after the use of the turbine beaver began. Significance was determined with the Student's t-test of means.

	Change in fitted lines: all observers (%)	**Mean change: Observer 1 alone** (%)	**Probability: Observer 1** (*P*)
Mallard (*Anas platyrhynchos*)	+ 70	+ 94	0.00008
American wigeon (*Anas americana*)	+ 69	+ 94	0.00006
Green-winged teal (*Anas crecca*)	- 19	+ 8	- -
Northern shoveler (*Anas clypeata*)	+159	+242	0.003
Northern pintail (*Anas acuta*)	+ 60	+ 66	0.03
Canvasback (*Aythya valisineria*)	+ 58	+ 67	0.013
Scaups (*Aythya affinis* and *A. marila*)	+ 33	+ 28	0.05
Goldeneyes (*Bucephala clangula* and *B. islandica*)	+ 2	+ 18	- -
Bufflehead (*Bucephala albeola*)	+ 9	+ 9	- -
Oldsquaw (*Clangula hyemalis*)	+ 58	+ 27	0.10
Scoters (*Melanitta* spp.)	+ 50	+ 23	0.007
All ducks	+ 46	+ 26	0.025

species surveyed over that extended period of time. Observer differences and annual oscillations seem not to have hampered our ability to use the data for this purpose.

Acknowledgments

Many people assisted with this project as observers, airplane mechanics, and administrators. Observers were J. Bartonek, C. Dau, D. Fortenberry, D. Groves, L. Haddock, R. King, C. Lostetter, W. Moholt, F. Roetker, J. Sarvis, P. Sekora, P. Shepherd, D. Spencer, D. Timm, J. Wendler and M. Zahn. The deHavilland turbine beaver airplane was designed by Jerry Lawhorn. Airplane mechanics included J. Hanley, E. Mitchell, R. Watson, and R. Zarkovich. R. Burt transcribed much of the historical voice tapes onto computer. Without the help of these individuals, the surveys would not have been possible.

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O'Neill, E. J. 1979. Fourteen years of goose populations and trends at Klamath Basin refuges. Pages 316-321 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Inc., Corvallis.

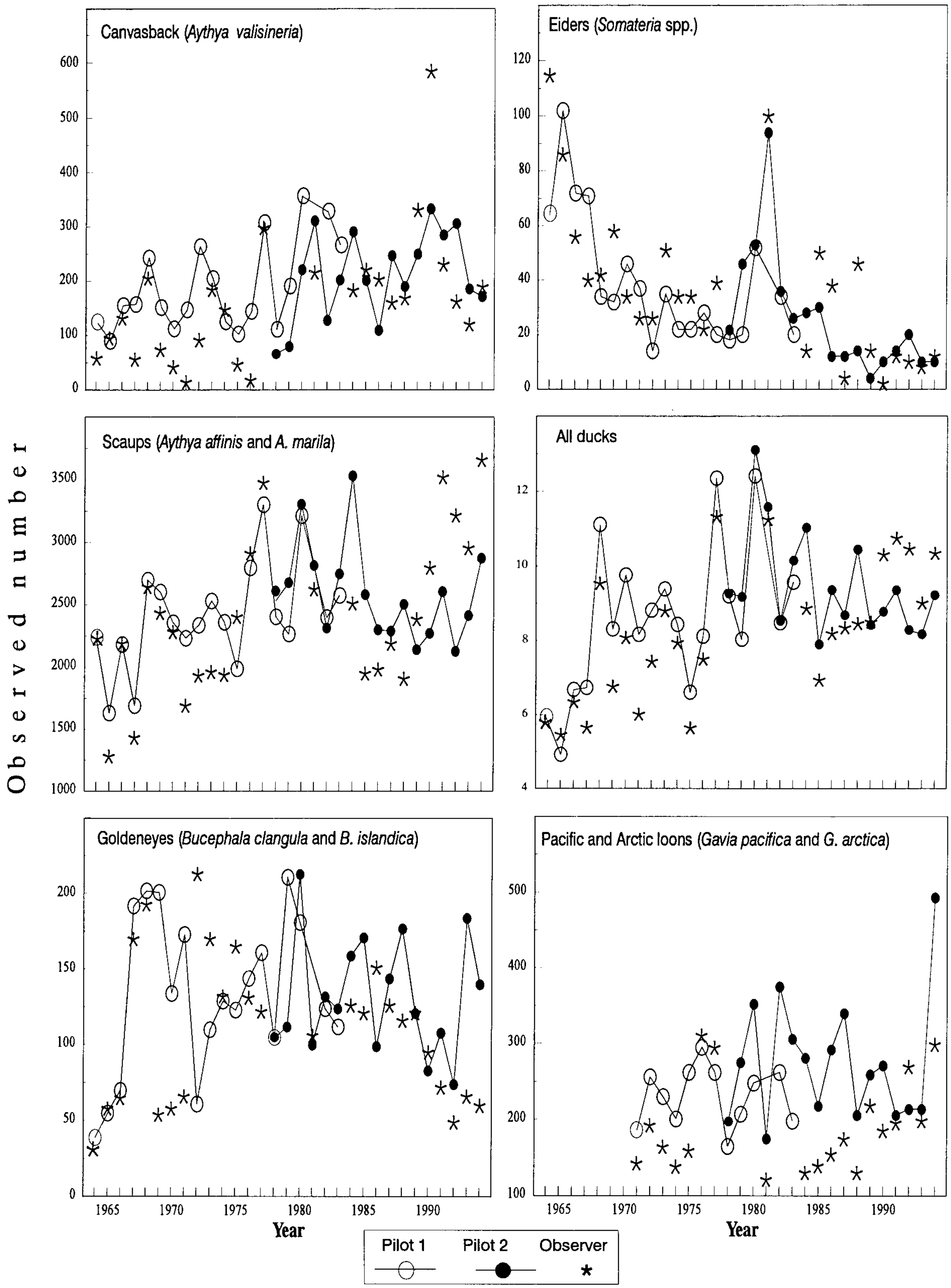

Fig. 4. Comparisons of number of birds recorded by Pilot-observer 1 and Pilot-observer 2 to their various right-seat observers during 1964-94, and to each other during 5 years of overlap.

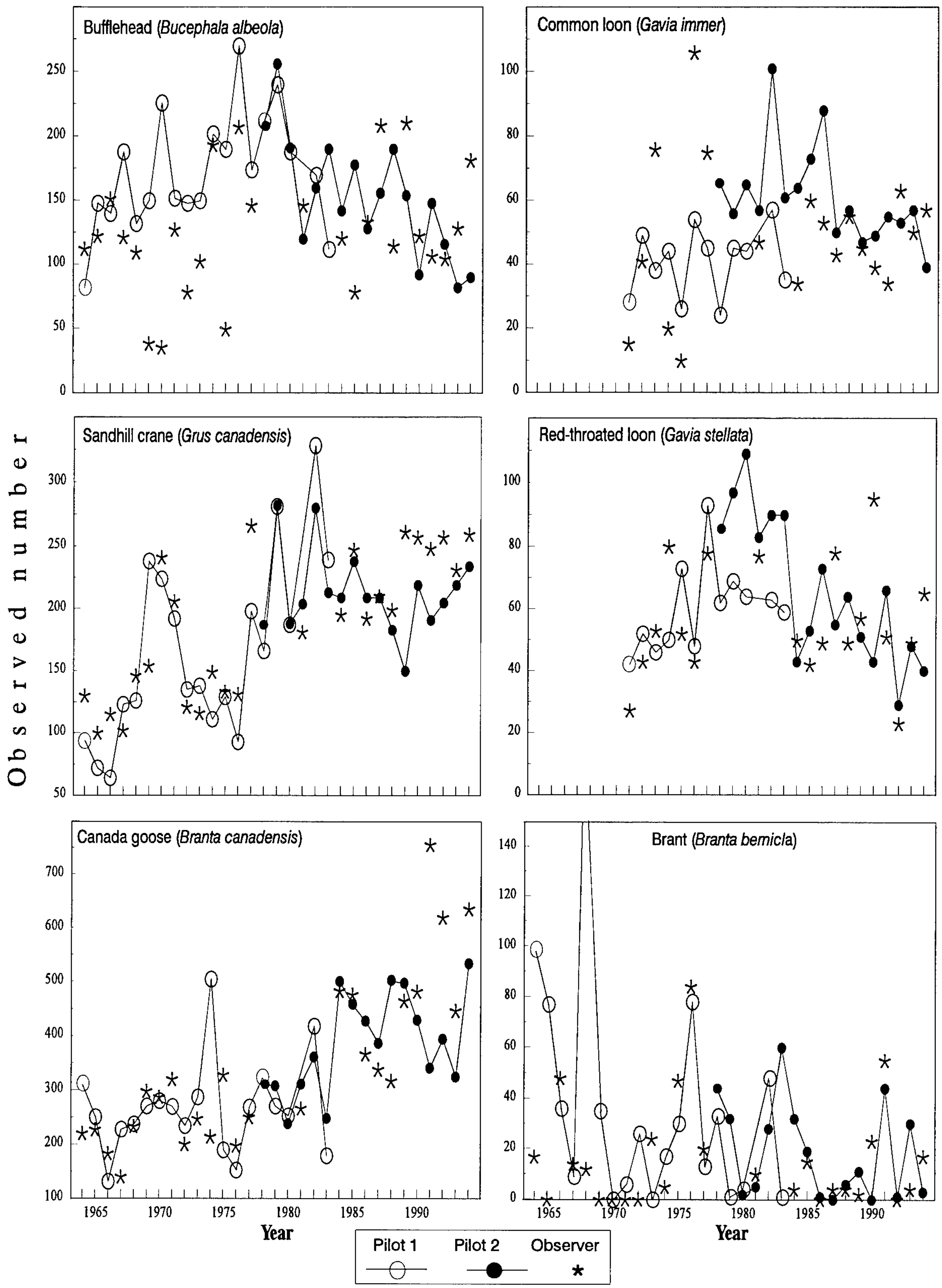

Fig. 4. Continued.

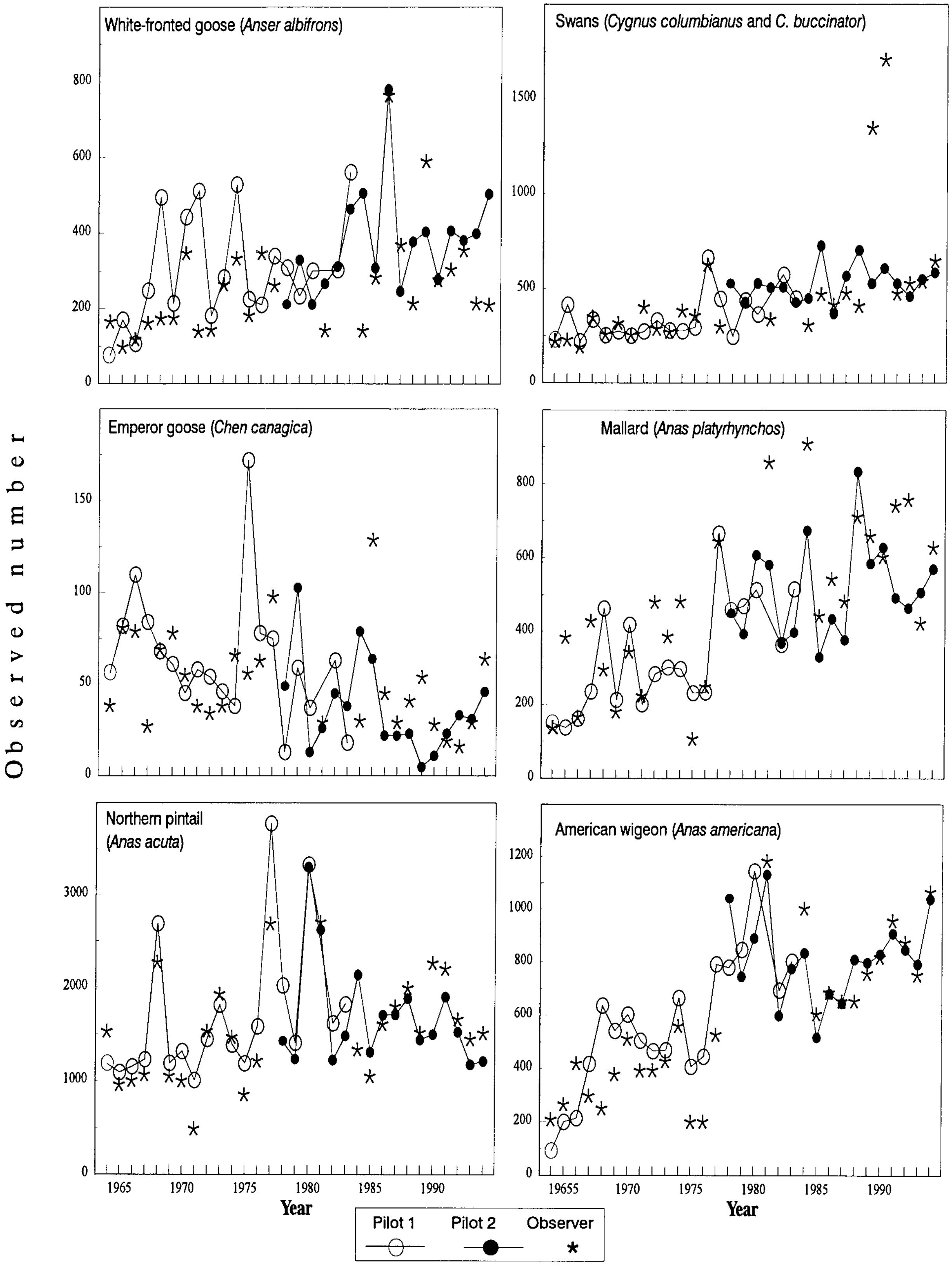

Fig. 4. Continued.

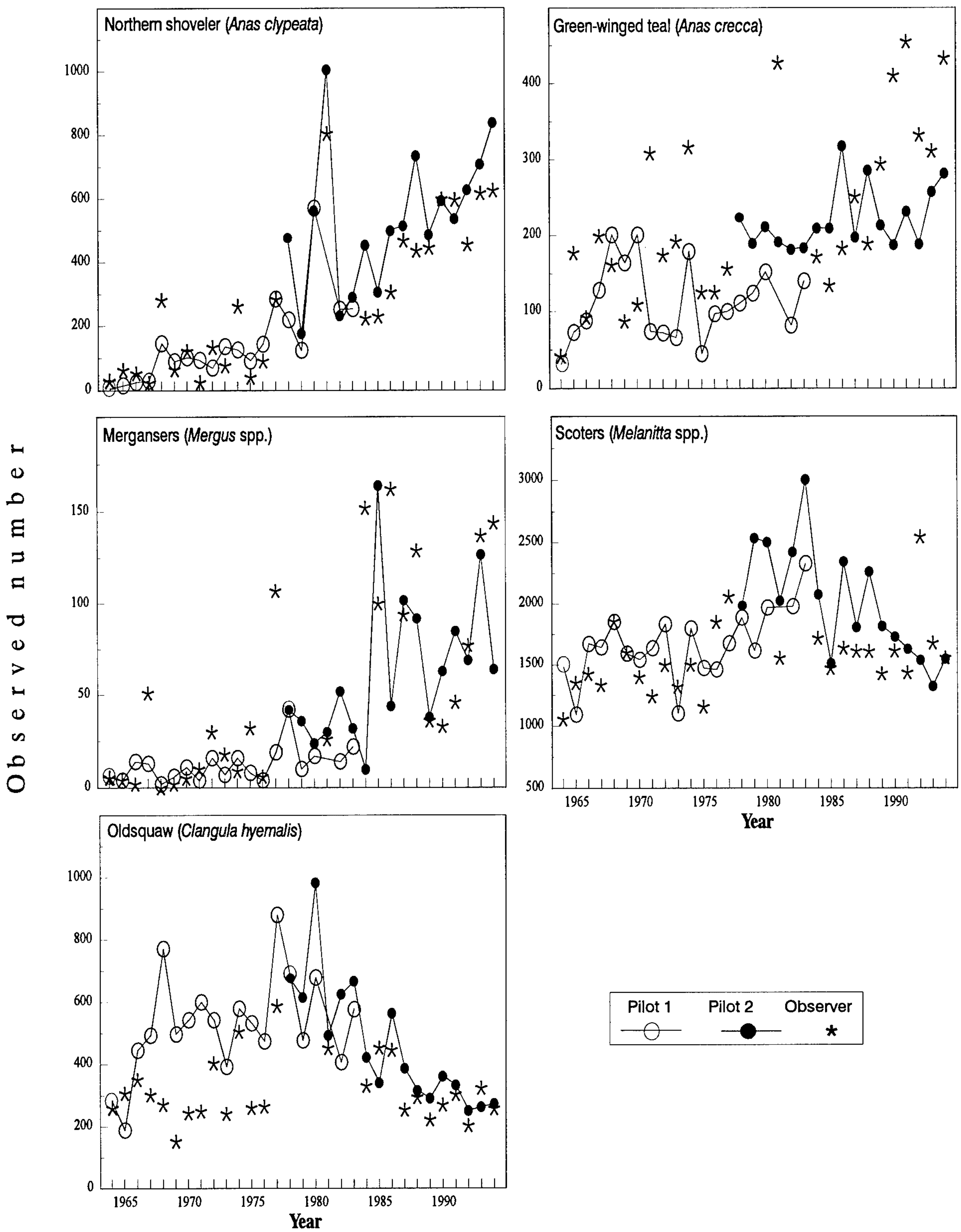

Fig. 4. Concluded.

Table 6. Number of birds seen by Pilot-observers 1 and 3 (as a percent of total birds seen) when Pilot-observer 2 was in the copilot seat and when Pilot-observer 2 was in the pilot seat.

Species	Birds observed (%)			Birds observed (%)		
	Pilot-observer 1 as pilot[a] Pilot-observer 2 as copilot[a]	Pilot-observer 2 as pilot[a] Pilot-observer 1 as copilot[a]	# of birds	Pilot-observer 3 as pilot[b] Pilot-observer 2 as copilot[b]	Pilot-observer 2 as pilot[b] Pilot-observer 3 as copilot[b]	# of birds
Mallard (*Anas platyrhynchos*)	97	117	3,632	92	117	3,233
American wigeon (*Anas americana*)	113	119	6,504	95	95	3,928
Green-winged teal (*Anas crecca*)	58	75	1,266	50	73	1,311
Northern shoveler (*Anas clypeata*)	96	93	2,469	49	73	2,462
Northern pintail (*Anas acuta*)	112	114	5,422	85	103	9,491
Scaups (*Aythya affinis* and *A. marila*)	91	98	1,507	76	79	13,126
Goldeneyes (*Bucephala clangula* and *B. islandica*)	109	107	1,209	109	72	833
Bufflehead (*Bucephala albeola*)	83	98	1,507	50	75	803
Oldsquaw (*Clangula hyemalis*)	66	84	5,038	89	103	2,415
Scoters (*Melanitta* spp.)	72	80	8,379	73	80	10,847
White-fronted geese (*Anser albifrons*)	103	111	2,721	77	99	2,732
Canada geese (*Branta canadensis*)	71	131	2,276	59	92	2,317
Swans (*Cygnus* spp.)	91	103	3,729	68	73	3,074
Loons (*Gavia pacifica* and *G. arctica*)	72	68	2,223	66	55	1,139
Red-throated loon (*Gavia stellata*)	77	56	641	48	87	311
Common loon (*Gavia immer*)	46	90	464	69	85	385
Average	85	97		72	85	
Standard error	5	5		4	4	

[a] Years 1979, 1980, and 1983.
[b] Years 1985, 1986, and 1988.

Smith, G. W. 1995. A critical review of the aerial and ground surveys of the breeding waterfowl surveys in North America. U.S. Fish and Wildlife Service Biological Science Report 5.

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A list of current *Information and Technology Reports* follows:

1. Population Biology of the Florida Manatee, edited by Thomas J. O'Shea, Bruce B. Ackerman, and H. Franklin Percival. 1995. 287 pp.

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3. Pine Plantations and Wildlife in the Southeastern United States: An Assessment of Impacts and Opportunities, by Arthur W. Allen, Yvonne K. Bernal, and Robert J. Moulton. 1996. 32 pp.

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National Biological Service

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